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and Infiltration with Polyacrylamide**

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FIVE-YEAR RESEARCH SUMMARY USING PAM IN FURROW IRRIGATION

R. D. Lentz and R. E. Sojka

A previous conference paper (Sojka and Lentz, 1996) presented an historic perspective and some general results of PAM investigations conducted at the USDA-ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho. This paper presents the experimental methods and summarizes results from those studies, conducted over a five-year period.

Studies initiated since 1991 determined best mode of PAM application, established PAM's effectiveness under different furrow irrigation scenarios and sought to define its potential environmental impacts (Lentz, *et al.*, 1992; Sojka and Lentz, 1993; Sojka *et al.*, 1994; Lentz, 1996; Trout *et al.*, 1995). Kimberly ARS field experiments initially sought to determine the PAM application method that most efficiently and effectively controlled furrow-irrigation induced soil loss and infiltration. We investigated the following PAM application parameters:

PAM form — dry granular, stock solution, oil emulsion

PAM type — polymer charge type, charge density, molecular weight

Application method — standard: PAM added to irrigation water; non-standard: PAM applied to furrow soil

Application strategy — timing, rate, and period of PAM application

Irrigation water quality —effect of a water's total salt or sodium adsorption ratio on PAM effectiveness

Experiments that examined effects of PAM type on furrow processes are presented in a separate paper (Lentz and Sojka, 1996). A series of studies documented PAM's usefulness over a range of furrow-irrigated field conditions. PAM was tested on different soils, furrow slopes, and using different furrow inflow rates and irrigation waters. Several studies examined PAM's environmental impacts. We first developed an analytical procedure for measuring PAM concentration in irrigation water to document the fate of PAM applied to

furrow irrigation inflows. A permanent PAM field site was established to study effects of long-term PAM applications on soil properties, microbiology (Watwood and Kay-Shoemaker, 1996), productivity and solute leaching. Another experiment documented PAM's influence on field runoff water-quality. Finally, a plot treated with excessive PAM additions was used to determine the potential for acrylamide-monomer accumulation in crop-tissue (Barvenik *et al.*, 1996).

Materials and methods

Field studies were conducted at the USDA-ARS Northwest Irrigation and Soils Research Laboratory at Kimberly, ID, and on fields of cooperating farmers near Filer, Hansen and Emmett, ID. Soils included Durixerollic Calciorthids, Xerollic Haplargids, and Haploxerollic Durargids. Surface soils in these studies were similar, though subsoils

varied among sites. Surface soil textures were silt loams (10-21% clay, 60-75% silt), organic matter was 10-13 g kg⁻¹, cation exchange capacity was 18-20 cmol_e kg⁻¹, electrical conductivity (EC, saturated paste extract) was 0.7-1.3 dS m⁻¹, ESP was 1.4-1.7, pH was 7.6-8.0 and calcium carbonate equivalent varied from 2-8%. Slopes were 0.5-7.0%. Seedbeds were disked or moldboard plowed, then roller-harrowed, and planted to corn (*Zea mays*), field beans (*Phaseolus vulgaris*) or potato (*Solanum tuberosum*). Row spacing was 0.56 m (22 in) for beans, 0.76 m (30 in) for corn and 0.92 m (36 in) for potatoes. Electrical conductivity of irrigation water was 0.1 at Emmett and 0.5 dS m⁻¹ at Kimberly, Filer and Hansen, and SAR was 0.4-0.7.

Furrows were shaped with a weighted furrow-forming tool. Only the alternate wheel-trafficked furrows were monitored in each study. Irrigation water was applied from adjustable spigots on gated pipe or syphon tubes set in concrete head ditches. Furrow lengths were 175-264 m (570-860 ft). Irrigation duration was 8-12 h. Inflow rates were 13-38 L min⁻¹ (3.5-10 gpm) during furrow advance, with highest rates on gentle slopes; subsequent inflows were reduced to 13-23 L min⁻¹ (3.5-6 gpm) when feasible.

Most studies employed a high molecular weight anionic PAM with moderate charge density, manufactured and marketed under the trade name Superfloc 836A by CYTEC Industries, Wayne, NJ. Superfloc 836A is a white granular material with a crystal size slightly larger than ordinary table salt. The granular PAM was used to prepare a 1200 or 2400 g m⁻³ (1200 or 2400 ppm) aqueous stock solution. During solution preparation, a motorized propeller vigorously stirred water into which granules were slowly sprinkled. Mixing continued for at least 20 min and the solution was allowed to stand a day or two to fully disperse. An emulsified form of this anionic PAM was also supplied by CYTEC. A stock solution was prepared from the PAM emulsion in a two-step dilution process. A 1% solution was mixed by slowly pouring the emulsion into a water-filled tank, along the edge of

Fig. 1 PAM application strategies employed in various studies

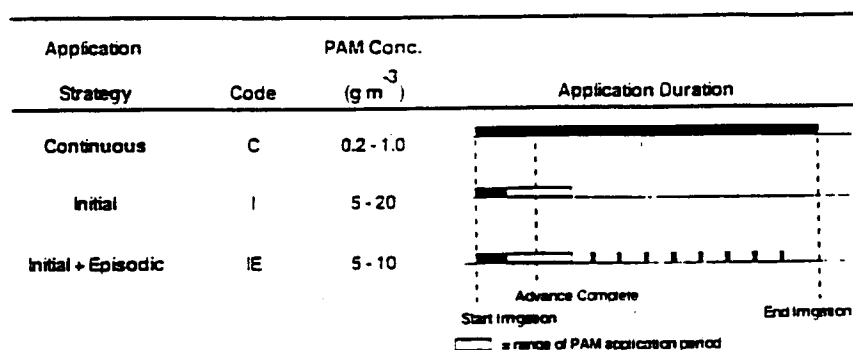


Table 1. Standard PAM treatments (PAM added to irrigation water).

Treatment Code	Timing, duration, and rate of PAM applied
C _{0.25} , C _{0.5}	Continuous PAM solution injection at 0.25 or 0.5 g m ⁻³ (0.25 or 0.5 ppm) throughout the irrigation
I _{5-20, 100%}	Initial. PAM solution injection at 5-20 g m ⁻³ (5-20 ppm) during the entire furrow advance (100%) and sometimes for an additional 30-90 min (110%+ advance)
IE _{5-10, 100%}	Initial-Episodic. PAM solution injection at 5-10 g m ⁻³ (5-10 ppm) during furrow advance or for an extra 30-90 min (110%+ of advance) plus additional episodic/intermittent short-term applications made subsequent to the initial dose. Episodic applications were 5-15 min in duration at 5-10 g m ⁻³ (5-10 ppm) PAM, applied every 1-4 h.
Dry I _{5-20, 100%}	Initial. PAM granules additions at 5-20 g m ⁻³ (5-20 ppm) during furrow advance and sometimes for an additional 30-90 min (110%+ of advance);

a vortex created in the water by a rapidly turning propeller. The 1% solution was then diluted to 1200 g m⁻³ (1200 ppm) using a similar protocol. Stock solutions were mixed using tap water having an EC = 0.9 dS m⁻¹ and a SAR = 1.5.

Furrow infiltration and soil-loss studies were randomized with three-six replications. PAM application procedures and furrow monitoring procedures were identical to those of Lentz et al. (1992). Positive displacement pumps metered stock solutions into the head of each furrow, at the position where turbulence from incoming water produced rapid mixing. We periodically monitored furrow inflows, measured outflows with long-throated flumes and determined runoff sediment content (Imhoff cone technique) during the irrigation (Lentz et al., 1992). Soil loss and infiltration were computed from field data with FUROFIGR, an analytical com-

puter program (Lentz and Sojka, 1994b; Sojka et al., 1994). Soil loss reduction was given as a percent and calculated as follows: 100 x (control - PAM-treated) / control. Net-infiltration increase was calculated with: 100 x (PAM-treated - control) / control.

Runoff water quality was assessed during several irrigations. Samples were taken from outflow monitoring flumes. We measured sample electrical conductivity, EC (Robbins and Wiegand, 1990), Total-P (Greenberg et al., 1992), Ortho-P (Watanabe and Olsen, 1965), Chemical oxygen demand, COD (American Public Health Association, et al., 1971), and NO₃-N (2.0 mM potassium benzoate eluent and liquid ion chromatography). Three samples were collected at 1-2 h, 5-6 h, and 8-10 h into each irrigation.

PAM Treatments. Standard PAM application treatments applied PAM to irrigation water, either as a stock

solution, or as dry granules. PAM was applied continuously, or for a specified period, starting when inflow began and continuing until the water first traversed the dry furrow (advance phase), or slightly longer. Three standard PAM application strategies were developed by varying the rate and timing of the stock solution application (Fig. 1, Table 1). Treatment codes indicate timing, concentration, and duration of application, where duration is given as the percent of the furrow advance treated. A fourth strategy applied PAM to the irrigation water as granules instead of a stock solution (Table 1).

Non-standard PAM application treatments applied PAM to furrow soils rather than irrigation water (Table 2). PAM was applied to furrows as a spray or broadcast in the upper furrow section.

PAM/water-quality interactions pertaining to infiltration were examined with a recirculating furrow infiltrometer. Kimberly (Snake R.) irrigation water was used as the low EC/low SAR source. Other water quality treatments were produced by increasing the EC and/or sodium adsorption ratio (SAR) of the Kimberly water with additions of NaCl, NaOH, or CaCl₂ salts. The four waters represented different combinations of low and high EC, and low and high SAR. Approximate treatment-water ECs were either 0.6 or 2 dS m⁻¹, and SARs were either 0.7 or 9. Each source water was amended with 0.25 g m⁻³ (0.25 ppm) PAM before water entered to infiltrometer. Hence, the PAM treatment was analogous to a C_{0.25}.

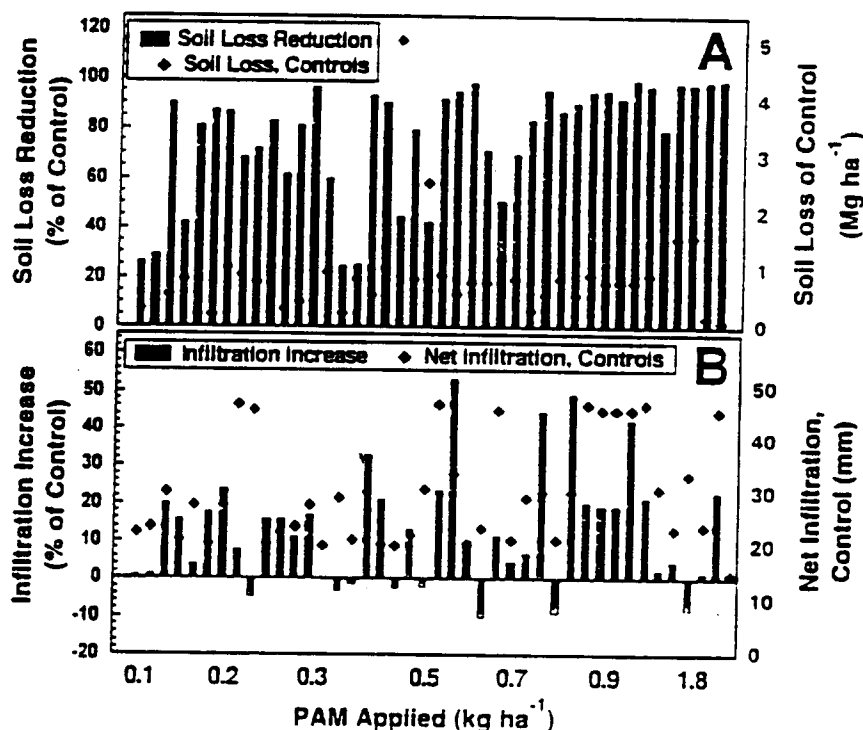
PAM-inflow interactions. This study examined the effect of doubling irrigation inflows from 23 to 46 L min⁻¹ (6 to 12 gpm) on PAM-I₁₀ treatment efficacy. The crop was potatoes. Furrows were 138 m (450 ft) long, with a slope 1.4%. Control and I₁₀-treated furrows at two inflow rates were monitored during an entire season.

Determination of PAM in irrigation water was accomplished with an instrumented flocculation (CSI) test developed at the Kimberly ARS Research Laboratory (Lentz *et al.*, 1996). The procedure adds a standard clay mineral to a PAM-amended water sample, which is agitated, then placed

Table 2. Non-Standard PAM treatments (PAM applied to furrow soils).

Treatment Code	Timing, duration, and rate of PAM applied
Spray	Sprayed same amount of PAM equal to that provided by I ₁₀ , ie. ~1.1 kg ha ⁻¹ (11b ac ⁻¹). Thus, 37.8 L (10 gal) of 600 g m ⁻³ (600 ppm) PAM stock solution was sprayed onto each 175 m (575 ft) long furrow.
BrdCst	Broadcast an amount of PAM granules equivalent to that of I ₁₀ along upper 30.5 m (100 ft) of furrow. Total PAM applied: 22.7 g (0.8 oz) for 175 m (575 ft) long furrow

Fig. 2 Control values and PAM-induced sediment-loss reductions (A) and net infiltration increases (B) are reported for treated irrigations or freshly cultivated furrows. Within each group, treatment parameters were identical, but PAM application strategy, irrigation duration, inflow rates and furrow slope varied between groups.



in a spectrophotometer. Flocculation and settling in the suspension as function of transmitted light is monitored over time. PAM concentration was correlated with settling-related transmittance changes. The procedure can detect as little as 0.1 g m⁻³ (0.1 ppm) PAM dissolved in irrigation water. Accuracy of the test ranges from ± 0.06 to 0.11 g m⁻³ (ppm) for 0–2.5 g m⁻³ PAM and ± 0.39 to 0.86 g m⁻³ for 2.5–10.0 g m⁻³ PAM. The CSI test provides a relatively simple, rapid, and accurate method for determining polyacrylamide in surface waters.

PAM-Fate Studies. PAM fate was examined by measuring in-stream PAM concentrations in furrows and

in tail- and waste-water streams that conveyed runoff away from the field (Lentz *et al.*, 1995). The wastewater stream may also receive tailwater contributions from neighboring fields. PAM treatments included an I₁₀ (10 g m⁻³ or 10 ppm PAM applied only as water first advanced down-furrow) and C₁ (1 g m⁻³ or 1 ppm PAM applied during the entire irrigation). The Dry I₁₀ granular-PAM vs I₁₀ treatments were also compared. Furrow-stream samples were collected at upper, mid, and lower positions along the 175 m furrows and a 200 m waste-water ditch that received the field runoff. Samples were taken 0.2 h (prior to curtailment of PAM application in

high-load treatments), ~2 h, and 7 h after the irrigation started.

Results and Discussion

Standard treatment effects. Results from three years study (Fig. 2) indicate that at least 0.7 kg ha⁻¹ (0.63 lb ac⁻¹) PAM should be applied during irrigation to produce consistently good erosion control. Lower application rates were effective under certain soil, field, or environmental conditions, but results were more variable. When the optimal application rate was used, PAM reduced furrow soil loss by an average of 94%, with reductions for individual irrigations ranging from 80-99%. Furrow infiltration varied appreciably from furrow to furrow, and PAM's influence on infiltration reflected this pattern. When > 0.7 kg ha⁻¹ (0.63 lb ac⁻¹) was applied, PAM produced an average net-infiltration increase of 15% (relative to controls), but for individual irrigations, the infiltration-increase ranged from -10 to 51%.

Other PAM application parameters—timing, duration and furrow stream concentration—also influenced PAM's erosion and infiltration management potential. The most effective treatments, IE_{5,100%} and I_{10,100%}, applied 5-10 ppm PAM during the entire furrow advance (Table 3). The IE_{5,100%} approach proved to be most efficient, giving maximum soil protection and infiltration benefits while using half the PAM required by the I_{10,100%}. Continuous PAM applications at < 1 g m⁻³ (< 1 ppm) provided about 75% the control for one-fourth to one-seventh the cost of the best treatments.

Erosion-control efficacy of solution- and dry-PAM application treatments was similar (Table 4). The average seasonal soil loss reduction was 84.3% for the dry-PAM application and 91.5% for the PAM solution treatment, although, differences were not significant ($p = 0.27$). An emerging trend among individual irrigations indicated the solution approach produced greater or equal soil-loss reduction than the dry method. In addition, dry PAM granules applied to the gated-pipe water stream did not completely hydrate and disperse. At season's end, partially hydrated slimy masses of PAM were discovered in

Table 3. Soil-loss reduction and increased net infiltration from PAM treatments, relative to control values. Average soil loss in control furrows was 0.9 Mg ha⁻¹ (0.8 ton ac⁻¹) and net infiltration was 39 mm (1.5 in.). Treatments were applied to new furrows and control soil losses were similar among the 12 h irrigations.

PAM Treatment Code (PAM applied, kg ha ⁻¹)	C _{0.25} (0.15)	IE _{5,60%} (0.45)	IE _{5,100%} (0.55)	I _{10,100%} (1.15)
Soil Loss Reduction, % (SD, %)	77.7 (3.1)	82.8 (12.2)	94.8 (3.4)	93.7 (2.7)
Net Infiltration Increase, % (SD, %)	12.8 (5.4)	15.8 (0.3)	17.6 (5.8)	19.5 (15)

Table 4 Seasonal sediment loss reduction (% of Control) for solution and dry granular application strategies.

Parameter	PAM Treatment			
	Solution		Dry	
Mean	Mean 91.5	SD* 3.0	Mean 84.3	SD* 9.7

*SD = standard deviation

the gated supply pipe, indicating an incomplete and inefficient use of the applied PAM. Emulsion PAM, used to prepare a stock solution which was then applied as I_{10,100%} treatments, was as effective for furrow irrigation management as the other PAM forms (data not shown).

Nonstandard PAM applications varied in their effectiveness. Spraying a 38 L (10 gal) of 600 ppm PAM solution on furrows was only moderately effective for controlling soil loss. Therefore, we doubled the application rate in the second irrigation. Results were similar in irrigation two, so spray data were reported as the mean of both runs. The spray treatment reduced soil loss in treated furrows by 33%, relative to controls, and had no effect on net furrow infiltration. The spray treatments disappointing performance might be improved by increasing the PAM application rate 10-fold (Fox and Bryan, 1992) or by applying a larger volume of a more dilute PAM solution (Roa, 1996; *this proceedings*).

Broadcasting 22.7 g granular PAM along the upper 30.5 m (100 ft) of furrows did a good job controlling soil loss, and significantly increased net infiltration into furrows. The BrdCst treatment reduced soil loss 71% relative to controls, compared to the 86% reduction produced by the standard

I₁₀ approach. Notably, only the BrdCst treatment increased furrow net-infiltration, by 32%, over that of the controls. The reason for this is not entirely clear. Concentrating the PAM in the upper furrow may better stabilize those soils in that reach of the furrow that has the greatest opportunity time and infiltration potential.

Runoff water quality. The I₁₀ PAM treatment decidedly reduced sediment, ortho-P, total-P and COD of treated furrow tailwater, but had little influence on runoff nitrate concentrations. The PAM I₁₀ treatment reduced soil loss an average 91% each irrigation compared to control furrows. Total seasonal soil loss was 3.14 Mg ha⁻¹ (1.4 T ac⁻¹) for control furrows and 0.35 Mg ha⁻¹ (0.2 T ac⁻¹) for the I₁₀ furrows. Tailwater ortho-P and total-P concentrations in control furrows were five to seven times that of the I₁₀ PAM treatment, and control COD levels were four times those of the I₁₀ treatment (Fig. 3). PAM also reduced runoff by 26%. Hence, the total nutrient losses from PAM-treated furrows were proportionally smaller than runoff concentration values suggest.

PAM-inflow. Doubling irrigation inflows from 23 to 46 L min⁻¹ (6 to 12 gpm) tripled soil losses in untreated furrows but did not apprecia-

Table 5. Soil loss and net infiltration for the standard I_{10} vs. two nonstandard PAM applications, Spray and broadcast (BrdCst). Irrigations were on newly formed 176-m (577-ft) furrows. (n=6 to 9)

Parameter	PAM Treatment			
	Standard Control	I_{10}	Spray	Nonstandard BrdCst
Soil-loss (Mg ha^{-1})	2.31 c*	0.33 a	1.54 b	0.66 ab
Net Infiltration (mm)	2.90 a	3.14 ab	2.70 a	3.83 c

*similar letters across rows indicate nonsignificant differences ($P < 0.05$).

Table 6. Mean soil loss per irrigation from furrows irrigated with typical inflows (23 L min⁻¹ or 6 gpm) vs. doubled inflows (46 L min⁻¹ or 12 gpm).

Parameter	PAM Treatment			
	1x Inflow Control	I_{10}	2x Inflow Control	I_{10}
Soil-loss (Mg ha^{-1})	0.64	0.08	1.90	0.15
(Standard Deviation)	(0.2)	(0.15)	(0.1)	(0.1)

bly change PAM's erosion control effectiveness (Table 6). Seasonal soil loss reduction was 89% for the 1x-inflow treatment and 93% for the 2x-inflow rate, and the difference was not significant. Thus PAM gives furrow irrigators a new option, they can increase furrow inflows, permitting more uniform water applications and potentially improving crop quality and productivity. Without PAM, increasing furrow inflows caused intolerable furrow erosion.

PAM/water-quality interactions. The influence of irrigation-water EC and SAR was observed in both the furrow infiltration rate and cumulative infiltration. Increasing the SAR of $C_{0.25}$ -amended Snake River inflows (low EC/low SAR source), from 0.7 to 9 resulted in decreased infiltration rates (Fig 4). Increasing the EC of Snake River water tended to produce higher infiltration rates for PAM-treated $C_{0.25}$ waters, although EC effects varied depending on the water's SAR. Our results suggest that changes in water quality will influence PAM's irrigation impacts. Since water quality can differ appreciably depending on source, geographic location and season-of-use, source-water chemistry should be a consideration in any PAM-application program.

Fate of applied PAM. PAM concentration in treated furrow runoff and tailwater depended upon the form of PAM applied (dry vs. solution), application strategy, time during the irrigation and sequence of irrigation. Note that noncontinuous PAM treatments in these two studies were longer than typical, i.e. extended beyond furrow advance, so that all furrows could be measured simultaneously during the later sampling times, and to provide more uniform tailwater conditions among the irrigations.

Although both dry and solution PAM applications did an excellent job controlling erosion, PAM losses for the two treatments differed appreciably. PAM runoff losses of Dry $I_{10, 170\%}$ were 5% of the total applied, compared to 3% losses for the solution $I_{10, 170\%}$ treatment. If only the furrow advance had been treated, PAM losses for the solution I_{10} would have been 1%, compared to 3% for the Dry I_{10} treatment. Hence, the PAM application recommended in the National Resource Conservation Service Practice Standard, solution $I_{10, 100\%}$, did produce the least PAM loss. During PAM injection, runoff from solution-treated furrows contained 6-10 g m⁻³ (ppm) PAM, while runoff from Dry I_{10} furrows contained 1-6 g m⁻³ (ppm).

Despite the lower PAM concentration, total PAM losses were greater in Dry I_{10} furrows. The dry PAM added to the Dry I_{10} gated pipe apparently did not completely dissolve. This explains why PAM concentrations were lower in the Dry I_{10} furrow streams than in the solution-treated streams during application. The undissolved PAM masses present in the Dry I_{10} gated pipe continued supplying PAM to the flows, even after the dry PAM application had ceased. Thus, PAM was lost in Dry I_{10} runoff throughout the entire irrigation.

In early irrigations on newly formed furrows, and while injection was occurring, the dissolved PAM-content in C_1 furrow-streams declined with distance downstream, whereas, PAM concentration in I_{10} furrow streams decreased only slightly with downstream distance (Fig. 5). In later sets on previously irrigated furrows, this PAM-decline with distance was more gradual for C_1 furrows, but remained similar to early irrigations for I_{10} furrows (Fig. 6). Within one-half hour after PAM injection in I_{10} furrows ceased, the dissolved PAM concentration in furrow streams had decreased to $< 0.25 \text{ g m}^{-3}$ (ppm). This was true for both new and repeat irrigated furrows. There was some indication in one irrigation that I_{10} stream PAM-content increased slightly late in the irrigation (Fig. 5). No PAM was being applied at this time, indicating that either this was a sampling or analytical error, or that previously applied PAM was being released back into the stream. Yet, PAM is irreversibly adsorbed to soil (Malik et al., 1991). Perhaps more PAM was applied to furrows than was required to saturate the soil surface. The excess polymer may have temporarily bonded to the PAM already coating the furrow perimeter, only to be released later in the irrigation set.

In the tailwater ditch, flows from I_{10} , C_1 , and control furrows mixed together. The combined flows in the early irrigation resulted in a PAM concentration of about 0.5 g m^{-3} (ppm) at the tail-ditch top (Fig. 5). If this was a dilution effect only, the concentration should have been at least 3 g m^{-3} (ppm). Apparently, aqueous PAM was binding to, and floccu-

lating the sediment contributed by control furrows, and hence was removed from the flow. Data from tail and waste water ditches indicate that, early in the irrigations, relatively higher PAM inflow concentrations drop to zero with distance downstream (Figs. 5 & 6). But, as the season progresses, the rate of decrease with distance declines (Fig 6). Thus, PAM concentration in the tail ditch had dropped below the mean detection limit at a point 93 m (300 ft) downstream of the field early in the season, and 530 m (1700 ft) downstream, late in the season.

Conclusions

PAM is an excellent soil erosion deterrent for furrow irrigated fields. It is a cost effective and safe technology, when used at the rates employed in these studies, and greatly reduces both sediment and chemical loading in agricultural runoff. The PAM employed was a moderate-charge-density (18% hydrolysis) anionic form with a molecular weight of 12-15 Mg mol⁻¹. When applied at rates greater than 0.7 kg ha⁻¹, PAM-treated irrigation water reduced furrow soil loss by an average 94% (80-99%) and increased net infiltration by an average 15%. Consistent control occurred when application rates were above 0.7 kg ha⁻¹. PAM reduced soil erosion losses well below soil-loss-tolerance limits on slopes ranging from 0.5 - 3.5%. A very effective approach added 10 g m⁻³ PAM to the irrigation water at the start of the set, continuing during or slightly beyond the furrow advance period.

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Fig. 3 Total-P (A), Ortho-P (B), NO₃-N (C) and chemical oxygen demand, COD (D) concentrations in runoff water from control and PAM 1₁₀-treated furrows.

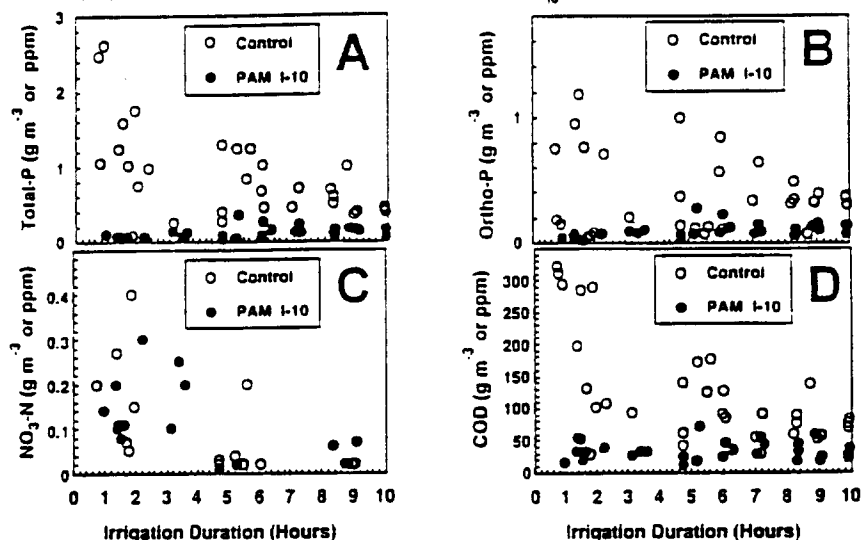
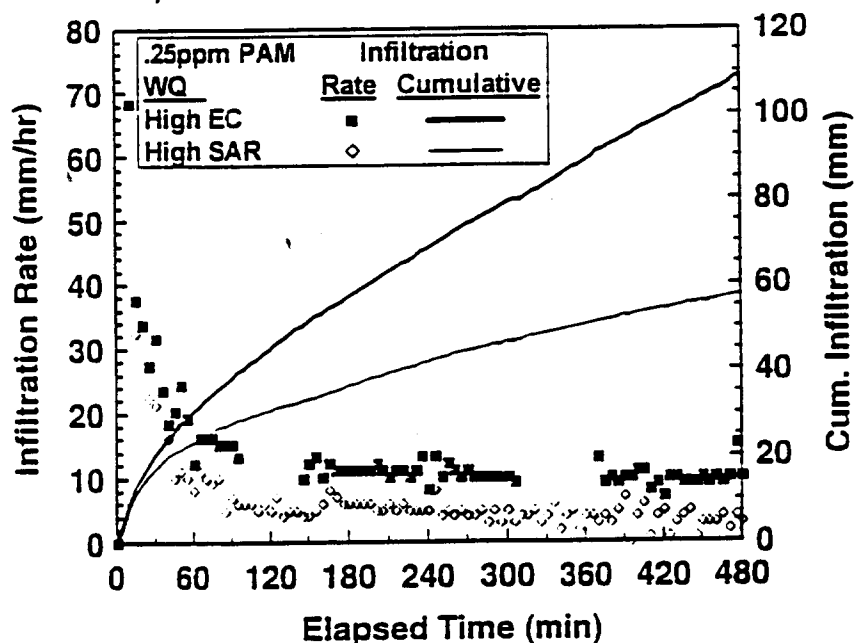


Fig. 4 The effect of source water-quality on furrow infiltration rate and cumulative infiltration of PAM C₁-treated furrows. The effect of increasing electrical conductivity (EC) and sodium adsorption ratio (SAR) of a furrow-infiltrometer water source is shown for newly formed furrows. Data from low-EC/low-SAR (unadulterated Snake R.) water was intermediate to that of the other treatments, and was not shown in the interest of clarity.



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Fig. 5 PAM concentration in I_{10} and C_1 , furrows and tail and waste water ditches for irrigation three, on newly formed furrows. PAM content in streams are shown for three different sampling times, and at several positions in furrow and tail water

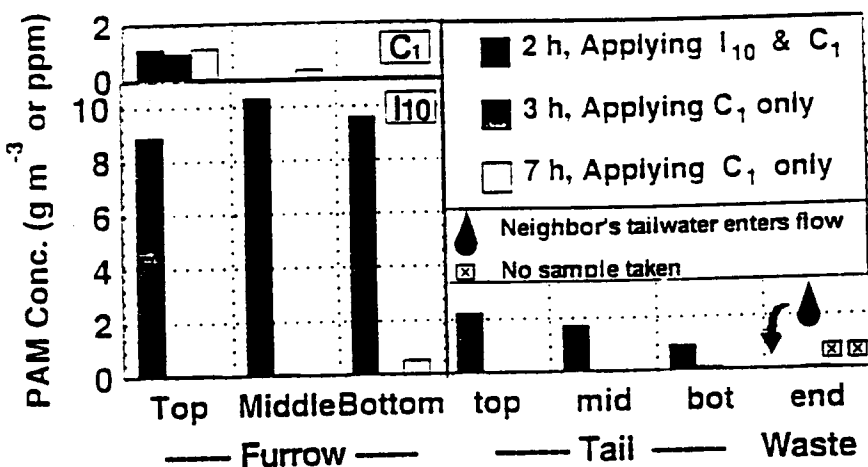
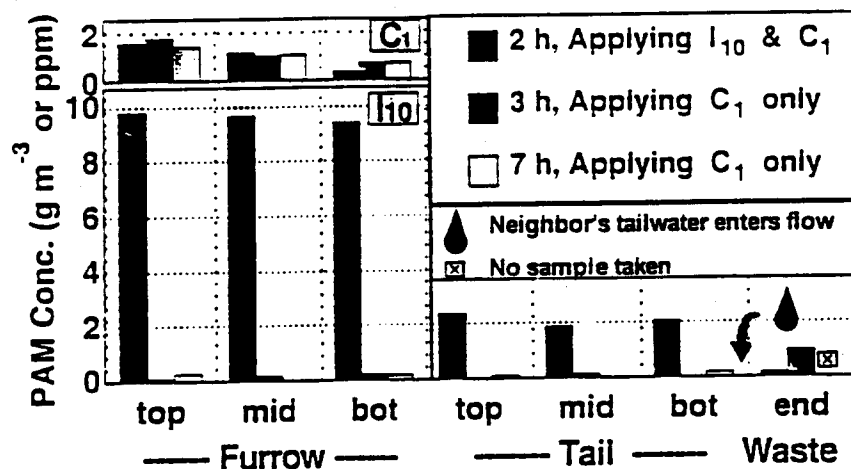


Fig. 6 PAM concentrations in I_{10} and C_1 , furrows and tail and waste water ditches for irrigation four, a repeat irrigation on furrows previously irrigated, and without an intervening cultivation. PAM content in streams are shown for three different sampling times, and at several positions in furrow and tailwater ditches.



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AN INTEGRATED APPROACH FOR WATER QUALITY: THE PAM CONNECTION— WEST STANISLAUS HUA, CA

by *M. McElhiney and P. Osterli*

USDA conservation and education agencies in partnership with a resource conservation district have successfully met water quality objectives the past five years through a comprehensive, integrated, locally managed watershed project in Stanislaus County, California (90 mi south of Sacramento in the San Joaquin Valley). The West Stanislaus Hydrologic Unit Area (HUA) project is one of 36 HUA's nationwide established in 1991 by USDA's "Water Quality Initiative."

Irrigation-induced erosion has been studied in the West Stanislaus Watershed area for over 15 years and these studies have contributed greatly to developing statewide predictive tools. Many Best Management Practices (BMPs) have been evaluated during this period. The innovative evaluation and use of PAM by HUA agencies is a more recent practice that has

proven to have potential for reducing significant amounts of sediment and pesticide residues from entering the impaired San Joaquin River.

The West Stanislaus Resource Conservation District (RCD) serves as the local, grass-roots sponsoring agency. RCD's are special districts formed for the purpose of addressing local resource conservation needs under Division 9 of the California Public Resources Code. There are 116 RCDs statewide that establish local conservation priorities and seek technical and financial assistance from a wide variety of local, state and federal agencies (conservation districts nationwide have established enduring relationships with USDA agencies through Memoranda of Understandings). RCD Directors are elected or appointed and volunteer their time to improve the resources in their respective communities.

The primary USDA agencies "working together" on the HUA are the Natural Resources Conservation Service — NRCS (formerly the Soil Conservation Service), the Farm Service Agency — FSA (formerly the Agricultural Stabilization and Conservation Service) and the University of California Cooperative Extension. Since the HUA began in 1991, over 25 additional local, state and federal agencies are participating or cooperating in varying degrees to implement their objectives in a coordinated manner.

HUA agencies conducted a comprehensive information and education program through newsletters, magazine articles, journals, tours, videos, brochures, fact-sheets, meetings, seminars, steering committees, formal and informal presentations throughout the western states, and one-on-one discussions with growers. The February 1996 issue of *National*